JOURNAL OF THE OPTICAL SOCIETY OF AMERICA VOLUME 49, NUMBER 5 MAY, 1959

Photoelectric Comparator for Wavelength and Intensity Measurements of Spectra*

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(Received October 3, 1958)

A photoelectric comparator is described that can be used for making wavelength measurements, intensity measurements, and observations of the shapes of spectral lines. The instrument is similar to one described by Tomkins and Fred with improvements in the optics.

INTRODUCTION

THE use of photographic plates for precision wavelength measurements requires very accurate position measurements of the spectral lines on the plates. In addition, it is highly desirable to obtain measurements of the relative line intensities and also to record the spectral line shapes. During the past few years several instruments have been built for such measurements. Among the most recent is the equipment at The Johns Hopkins University described by G. H. Dieke, D. Dimock, and H. M. Crosswhite.[1] They used a photoelectric setting device, as described by F. S. Tomkins and M. Fred,[2] on a conventional comparator along with automatic punching of IBM cards with the measurements. The design of the photoelectric setting device for the photoelectric comparator to be described here is very similar to Tomkins and Fred's device but the optics have been rearranged and improved. This gives a more rugged construction, a better density reading, a larger light intensity on the photomultiplier tube with less light on the photographic plate, and makes possible a better setting on the true line position.

DESCRIPTION OF THE PHOTOELECTRIC COMPARATOR

The photoelectric comparator and its accessory equipment are shown in Fig. 1. In this picture the light shield that covers the comparator has been removed. A conventional comparator with a precision screw that can be read directly and easily to 0.001 mm on the dial was used for the position measurement. The carriage was loaded with a 5 pound weight and all of the original optics replaced with the optics to be described. Figure 2 shows the apparatus added to the rear of the comparator and Fig. 3 shows the new optical system. This optical system plus a display of the photomultiplier tube signal on an oscillograph provides the fiducial position for each position measurement, a measure of the transmission of the spectral line on the plate, and the observation of the spectral line shape.

The image of the single filament lamp is only about 2.5 microns wide at the photographic plate, thus allowing the oscillograph screen to show practically the full resolution of the recorded spectral lines. Horizontal and rotational adjustments of the lamp permit parallel alignment of its filament image with the spectral lines. The length of the filament image may also be adjusted to any convenient length less than 0.5 mm.

The horizontal scanning prism is rotated at the rate of 30 revolutions per second with a synchronous motor, resulting in the image of the single filament lamp sweeping unidirectionally across the photographic plate at the rate of 120 per second.

The vertical scanning prism is rotated slowly in either direction at the command of a three position switch mounted on the side of the oscillograph (see Fig. 1). The axis of rotation of this prism is adjustable so that the image of the single filament lamp can be moved

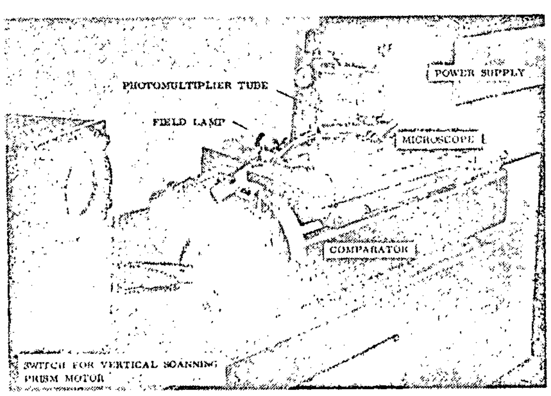

FIG. 1. The photoelectric comparator and its accessory equipment.

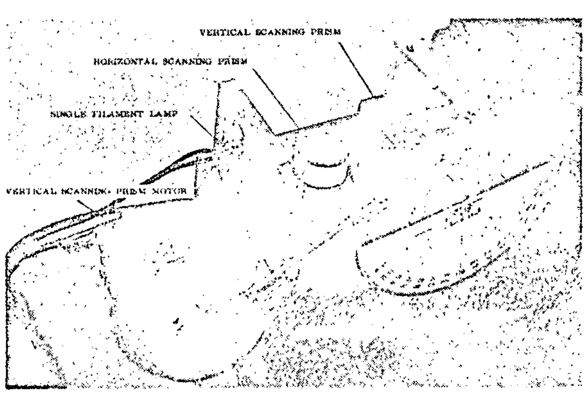

FIG. 2. Rear of comparator with dust cover and field lamp removed.

* Work done under the auspices of the U. S. Atomic Energy Commission.

[1] Dieke, Dimock, and Crosswhite, J. Opt. Soc. Am. 46, 456–462 (1956).

[2] F. S. Tomkins and M. Fred, J. Opt. Soc. Am. 441, 641–643 (1951).

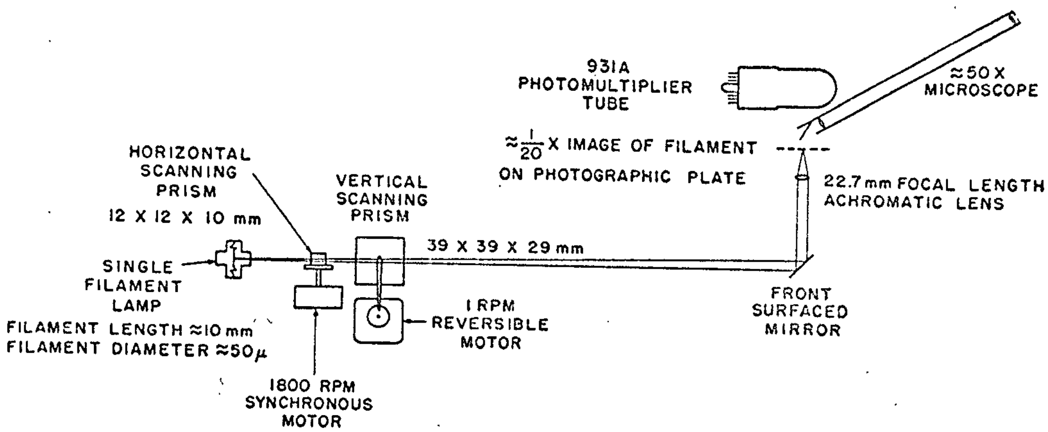

FIG. 3. Photoelectric comparator optical system.

precisely along approximately 1.5 mm of the spectral lines.

The mounting of the photographic plate on the comparator carriage is shown in Fig. 1. The original glass plate of the comparator was replaced by a metal plate with a rectangular hole somewhat longer and not quite as wide as the photographic plate. The back bar, against which the photographic plate rests, is spring loaded. The bar on the front has two adjustment screws that are used to align the spectrum on the photographic plate parallel with the comparator carriage motion.

The photomultiplier tube and microscope mounting are shown in Fig. 1. The microscope is used for visual inspection for blemishes on the spectral lines. It is not used for position settings.

The output of the photomultiplier tube goes directly to the y-axis amplifier of a 5-in. oscillograph with a long persistence picture tube. The x-axis amplifier is supplied with a 60-cycle ac voltage making the horizontal sweep of the light spot on the oscillograph screen go in one direction every other 1/120 second and in the opposite direction for the second 1/120 second. Since the sweep of the single filament lamp across the photographic plate is in the same direction each 1/120 second, the oscillograph screen shows both the normal and the mirror image transmission curve of the photograph plate with a horizontal magnification of about 1000. The comparator carriage is moved so that the two transmission curves of the spectrum line being measured are superimposed for the correct comparator setting. This setting is dependent only on the phasing of the rotating horizontal scanning prism to the oscillograph x-sweep and the positions of the elements of the optical system, if the base line on the oscillograph screen with a clear photographic plate is flat. To make this base line flat, both the single filament lamp and the photomultiplier tube have good, but not exceptional, dc power supplies. The phasing adjustment of the horizontal scanning prism to the oscillograph x-sweep is done by rotating the motor that turns the horizontal scanning prism. While the comparator is in use this motor is never stopped. The phase shift between the motor mounting and the motor shaft is considerable during the first few hours but has been shown to be constant for many months after a day's warmup. All the stationary elements of the optical system are locked in place after all adjustments have been made. The oscillograph screen can be calibrated to give directly the transmission of the photographic plate. With the 5-in. oscillograph screen this can be measured to about 2%, which is better than needed for most photographic emulsions. The oscillographic screen pattern is also used to classify the spectrum line shape into several types.

The comparator is shock mounted to a very sturdy table and is covered with a black cloth light shield to protect the photomultiplier tube from the room lights.

DISCUSSION

Some of the advantages of the optical system used in this comparator come from the use of a very narrow line of light that is imaged on the photographic plate as is done in the Knorr-Albers microphotometers[3] of the Leeds and Northrup Company. The low stray light of this type of optics was shown by A. Strasheim,[4] who compared a number of microphotometers with differing optical systems, to be of importance for the accurate measurement of spectral line densities and also when complex spectra taken with a very narrow spectrograph slit are to be measured.

The vertical scanning prism is used for a precision movement of the line of light along a spectral line and (or) between two spectrograms. Random variations in the setting along the line can be observed and the average value taken. If a blemish is observed at one place on a line this place can be ignored and the good portion of the line used for the setting.

[3] H. V. Knorr and V. M. Albers, Rev. Sci. Instr. 8, 183–184 (1937).
[4] A. Strasheim, Spectrochim. Acta 4, 489–495 (1952).

Approved For Release 2004/02/12 : CIA-RDP79B00314A000500030002-2

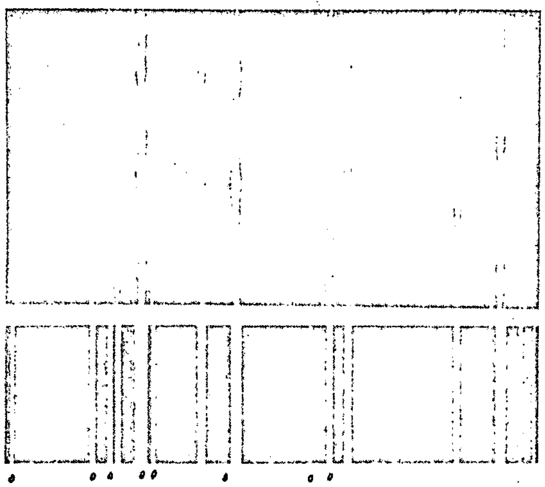

FIG. 4. Interferogram (top) and spectrogram (bottom) taken with a narrow spectrograph slit showing single lines on spectrogram (o) that are resolved on interferogram into more than one line.

The use of this photoelectric comparator is not restricted to ordinary spectrograms. For example, Fig. 4 shows the increased resolution obtained when the spectrograph is crossed with a Fabry-Perot interferometer. A narrow spectrograph slit was used in order to resolve the free spectral range of the interferometer. The interferogram can be measured along the spectrograph dispersion in the same way as the spectrogram with the exception that a short filament image length is used along with the vertical scanning prism to select the center of an interferometer fringe for the setting. The position accuracy will be no greater than with ordinary spectrograms except for lines close together which are now resolved by the interferometer. This technique is most valuable for complex spectra very rich in lines and calling for the highest possible resolution to separate the lines. The time required to measure interferograms in this way is little longer than that required for spectrograms and much shorter than the time required to measure each interferometer pattern in the usual way by determining the ring diameters. A comparison standard spectrum cannot be used with this technique, hence several lines on each interferogram are measured in the usual way and then used to find the formula relating the position measurements to wavelengths. Another advantage of measuring interferograms is that it reduces the photographic adjacency effects for lines close together.

If a very small spot of light is desired instead of a line of light, the single filament lamp can be replaced by a zirconium concentrated-arc lamp. The very small and low wattage lamps are not satisfactory due to the wander of the position of the bright spot of light, but a larger wattage lamp with a piece of metal foil containing a small pin hole in front of the lamp works very well.